N89-12585

CHARACTERIZATION OF A GRAPHITE EPOXY OPTICAL BENCH DURING THERMAL VACUUM CYCLING[1]

Patricia A.Hansen, Teresa K. Jenkins,
Carl R. Maag, and Daniel M. Taylor
Jet Propulsion Laboratory
California Institute of Technology

ABSTRACT

In-situ monitoring of the Wide-Field/Planetary Camera, a Hubble Space Telescope science instrument, was performed in a vacuum environment to better understand the formation of ice on cooled optical detectors. Several diagnostic instruments were mounted on an access plate and viewed the interior of the instrument housing and the graphite epoxy optical bench. The diagnostic instruments were comprised of the following: a TQCM (Temperature-Controlled Quartz Crystal Microbalance), a Pressure Gauge and an Optical Witness Sample. This paper describes the instrumentation and the rationale for choosing this instrumentation. In addition, the performance of the instrumentation during monitoring operations will be presented.

INTRODUCTION

An in-depth contamination study of the Wide-Field/Planetary Camera (WF/PC) was conducted by the Jet Propulsion Laboratory (JPL).[2] As part of this study the formation of ice on the cooled detectors was investigated. During previous system thermal vacuum tests, a contaminant, thought to be ice, was observed on the detectors. This contaminant was easily removed when the detectors were warmed up while under vacuum. After this period, the detectors were cooled and no contaminant, or ice, was seen on the detectors during imaging.

This phenomena was thought to be the result of water desorption from the graphite epoxy optical bench material (ref. 1). To better understand this phenomena, several diagnostic instruments were proposed for in-situ monitoring

---

[1] This work has been carried out by the Applied Technologies Section, Jet Propulsion Laboratory, California Institute of Technology and was sponsored by the National Aeronautics and Space Administration.

[2] Carl R. Maag: Results/Findings of the WF/PC Contamination Team, Draft. JPL Internal Document, Jet Propulsion Laboratory, Pasadena, CA, May 1987.

of the WF/PC during a system thermal vacuum test. The diagnostic instruments included a Temperature-Controlled Quartz Crystal Microbalance (TQCM), a Pressure Gauge and an Optical Witness Sample (OWS). These instruments were mounted on an access plate and viewed the interior of the instrument housing and the thermally blanketed graphite epoxy optical bench.

One of the principal ground rules was that the diagnostic instrumentation could not introduce contaminants into the WF/PC housing and could not change the existing heat flow paths. Thus the instrumentation was subjected to rigorous preconditioning prior to installation on the WF/PC housing. In addition, only low outgassing materials were used on the access plate.

During the system thermal vacuum test additional diagnostic instrumentation and contamination monitoring devices were used to measure the test environment. Only the access plate instrumentation will be discussed in this paper. A summary of the access plate instrumentation results is also presented. An in-depth discussion of the TQCM measurement techniques and data reduction is the subject of another paper included in this conference (ref. 2).

WIDE-FIELD/PLANETARY CAMERA

The WF/PC is the radial science instrument on the Hubble Space Telescope (HST) developed and built by the JPL and the California Institute of Technology. The scientific objectives of the WF/PC are to provide photometrically and geometrically accurate, multiband observations of stars and extended sources over a wide field-of-view (FOV) on the HST, and to provide very high angular resolution photometrically and geometrically accurate, multiband images of the solar system and its astronomical objects.

The WF/PC contains two complete optical relay and detector systems as shown in Figure 1. Each system is capable of producing a four-part image mosaic. One relay system operates for wide-field work and the other operates for planetary or high resolution work. Only one optical system provides images at any given time.

Once the relay optics intercept the light, they reflect it through the primary and secondary optics to the detectors located in the rear of the optical assemblies (in the camera heads). The eight (8) detectors (one in each of the four camera heads for either the wide-field or planetary system) contain charge coupled devices (CCDs). The CCDs are cooled to a nominal temperature of -90°C to suppress their dark current and to improve their performance.

WF/PC CONTAMINATION STUDY

The WF/PC contamination study investigated the formation of ice on critical surfaces such as the CCD windows and the Thermoelectric Coolers

(TEC). The goal of this investigation was to prevent the formation of ice on optical surfaces and to develop operational strategies to respond to ice formation if it reoccurred during flight operations.

Models predicting the formation of ice were developed to define and quantify the parameters associated with this phenomena. As this phenomena was thought to be the result of water desorption from the graphite epoxy optical bench material, a model of the dew point inside the housing was derived for external vacuum conditions.[3] When the temperature of a surface such as the CCD windows or TECs are below the dew point temperature (and below the freezing point of water) ice will form on these surfaces. This dew point model was then used to develop operational strategies for cooling the detectors.

Several layers of MLI (multilayer insulation) blanket were removed from the housing to decrease the nominal operating temperature of the WF/PC by several degrees. Scenarios were developed to predict the time delay after launch for the dew point temperature of the outgassing water, or contaminant, to be below the temperature of the CCD windows.[4] The operating temperature of the detectors was raised ten degrees to allow early operation of the detectors. It is believed that these changes will result in ice free operation of the cooled detectors 30 days after launch.

The diagnostic instrumentation was proposed for in-situ monitoring of the optical bench and housing to quantify the initial parameters of the derived models. A TQCM was employed to measure the adsorption and desorption of volatile condensible material (VCM) on the surfaces in the WF/PC, primarily the graphite epoxy optical bench and the electronics. The pressure gauge was employed to measure the initial water content of the optical bench (i.e. the partial pressure of water). The OWS was used to measure any change in reflectance of an optical surface due to the deposition of outgassed material on that surface. The access plate was a structural member only.

DIAGNOSTIC INSTRUMENTATION

INSTRUMENT CONFIGURATION

The diagnostic instrumentation was mounted on the access plate as shown in Figure 2. The operational constraints of the pressure gauge required it be mounted on an extended inlet tube outside the WF/PC shrouds. The inlet tube

---

[3] Jack B. Barengoltz: A Model of the WF/PC Dew Point. JPL Interoffice Memorandum No. 3543:87:0010, Jet Propulsion Laboratory, Pasadena, CA, January 15, 1987.

[4] Jack B. Barengoltz: WF/PC Thermal Blankets Revisited. JPL Interoffice Memorandum No. 3543:87:0084, Jet Propulsion Laboratory, Pasadena, CA, May 14, 1987.

was mounted on the access plate as shown in Figure 2. The access plate was mounted on the WF/PC housing as shown in Figures 3 and 4.

ACCESS PLATE

The goal of the monitoring was to better understand the formation of ice on the detectors using "passive" measurement techniques. As such, it was imperative that the access plate and diagnostic instrumentation did not change the existing WF/PC heat flow paths or introduce volatile condensible material (VCM) into the housing.

VESPEL (SP-1) was chosen as the material for the access plate as it provided good thermal isolation from the WF/PC housing and the vacuum chamber shrouds, was easily machined and was a low outgassing material. The access plate was subjected to a 80°C ± 2°C vacuum bakeout for 36 hours at 1×10^{-6} torr prior to installation onto the WF/PC housing. Swab sampling was performed prior to installation to verify that the access plate would not contaminate the interior housing of the WF/PC during test.[5]

Freon TF (Burdick-Jackson HPLC purity 1,1,2-Trifluorotrichloroethane) was used to clean the access plate and the external surfaces of the diagnostic instrumentation prior to installation onto the WF/PC housing. The NVR (nonvolatile residue) was removed from these surfaces and thus prevented the introduction of organic contaminants into the WF/PC housing.

TEMPERATURE-CONTROLLED QUARTZ CRYSTAL MICROBALANCE

A temperature-controlled quartz crystal microbalance (TQCM) performed in-situ measurements of adsorbed and desorbed VCM on surfaces in the WF/PC, primarily the graphite epoxy optical bench and electronics. The TQCM was instrumented with 15 MHz optically polished crystals (ref. 3). The crystals were coated with aluminum to be representative of a reflective optical surface.

The heat generated by the TQCM electronics was removed by a gold plated copper heat sink which was thermally coupled to a heat exchanger maintained at 10°C ± 5°C. This provision, suggested by the manufacturer, provided increased accuracy of the TQCM measurements (ref. 3). In addition, this provision allowed the contamination loading from the WF/PC optical bench and housing to be monitored without changing the existing heat flow paths.

The TQCM monitored the access plate vacuum bakeout. As a monitoring device, the TQCM was subjected to a 80°C ± 2°C vacuum bakeout for 36 hours.

---

5 Patricia A. Hansen: Results of the WF/PC Access Plate Bakeout. JPL Interoffice Memorandum No. 354C:88:0012 (ST-DFM 1140), Jet Propulsion Laboratory, Pasadena, CA, January 21. 1988.

Prior to installation on the access plate, the exterior surfaces of the TQCM were cleaned.

PRESSURE GAUGE

The pressure gauge was a Series 275 Convectron gauge from Granville-Phillips Company (ref. 4). It was capable of providing a pressure measurement from 1000 torr to 10^{-3} torr. The gauge tube contained a temperature compensated heat loss sensor which utilized conduction cooling to sense pressure at lower pressures. At higher pressures, it utilized convection cooling in which gas molecules were circulated through the gauge tube by gravitational force.

Prior to installation on the access plate, the pressure gauge was calibrated to extend the nominal useful range from 1×10^{-3} torr to 2×10^{-4} torr. The pressure gauge was also subjected to a 80°C ± 2°C vacuum bakeout for 24 hours at 1×10^{-6} torr. The exterior surfaces of the pressure gauge were cleaned prior to installation on the access plate.

The pressure gauge inlet tube was extended to allow the pressure gauge to be mounted on the access plate but reside several inches away from the access plate due to operational constraints. During operation, the pressure gauge was mounted to remain in a horizontal position and at ambient temperatures. Although not shown mounted on the access plate in Figure 4, the pressure gauge is presented in Figure 5.

OPTICAL WITNESS SAMPLE

The optical witness sample (OWS) was an optically polished aluminum sample. The sample was coated with MgF_2 to simulate an optical surface. The OWS was installed in a holder for ease of handling prior to installation. An example of the OWS installed in a holder is shown mounted on the external test fixture in Figure 6.

The reflectance of the OWS was measured at several wavelengths (1216 Å, 1608 Å, 2200 Å, 2537 Å and 3130 Å) prior to installation on the access plate. The OWS holder was vacuum baked with the access plate.[5] The exterior surfaces of the holder were cleaned prior to the OWS installation.

THERMAL VACUUM TEST MONITORING

The TQCM and pressure gauge continuously monitored the WF/PC optical bench and housing during the system thermal vacuum test. The WF/PC test profile simulated three flight operational conditions: nominal operational conditions, a flight hot case and a flight cold case. During these profiles

the temperature of the TQCM was varied to measure the relative volatility of the surface contamination from the optical bench and housing.

The OWS was continuously exposed to the WF/PC housing and optical bench. The OWS was not temperature controlled and was coupled by radiation to the housing and optical bench. Thus the OWS followed the temperature profile of the housing and optical bench and varied from approximately 35°C to -5°C.

RESULTS

The temperature of the TQCM was varied to measure the relative volatility of the surface contamination from the optical bench and housing which was held at a constant temperature during the test profiles. Self-contamination of the TQCM was considered highly improbable due to the rigorous preconditioning program of the access plate and diagnostic instrumentation. Therefore, the contamination source was internal to the WF/PC. The TQCM measured two groups of contaminants as a result of varying its temperature and the optical bench and housing temperature. As a result of these measurements, it was concluded that the TQCM collected an organic contaminant, not ice, when cold. The source of this contamination was not identified as the optical bench and housing are composed of many subassemblies (e.g. electronics, camera head, mechanisms, etc). However, additional measurements indicated the contamination source was strongly correlated to the operation of the electronics bays. Although surface contamination was detected by the TQCM, additional temperature cases showed that the detectors could be outgassed without detector performance loss. An in-depth discussion of the TQCM results is the subject of another paper included in this conference (ref. 2).

During operation, the TQCM was not operated at a temperature cold enough to collect ice. For operational temperatures below -60°C, the manufacturer suggests using a CQCM (Cryogenic Quartz Crystal Microbalance) (ref. 3). However, ice formation on the detectors (i.e. the CCD windows) was not expected as the amount of adsorbed water in the graphite epoxy optical bench and housing had been limited by the use of an ultradry nitrogen purge prior to test and the use of operational strategies during the test. The ultra-dry nitrogen purge system and the operational strategies are the subject of another paper included in this conference (ref. 5).

The TQCM measurements identified that water (ice) was not the only contaminant inside the WF/PC housing and optical bench. Flat field imaging was performed to verify that the operational strategies did indeed result in ice free operation of the cooled detectors (ref. 6). These images were not obscured as in previous tests. Therefore, these operational strategies resulted in ice free operation of the cooled detectors.

The pressure gauge was initially recommended so that its measurements could be used to derive the partial pressure of water inside the WF/PC, it was found that these measurements needed to be extended into the 10^{-5} torr range. In the event of ice formation on the CCDs, the pressure gauge would have been used to determine the actual vapor pressure of the ice, or contaminant. In

addition, the pressure gauge would have been used to determine the vapor pressure of the ice during the detector warmup/ice removal sequences.

As the detectors did not collect ice, the pressure gauge was only used to measure the pressure differential between the WF/PC housing and the vacuum chamber during chamber pump down and purging sequences. The rate of diffusion of the purge gas out of the camera and the effectiveness of the vent tube were measured. These measurements were correlated with the previous predictions.[6]

The OWS was measured immediately after test. The results of these measurements showed the reflectance of the OWS did not degrade beyond three (3) percent at Lyman-Alpha wavelengths. The OWS reflectance measurements indicated that if warmed to room temperature and atmospheric pressure, the contaminant did not cause a loss in reflectance on an optical surface (i.e. the CCD windows).

CONCLUSIONS

Significant information was obtained with in-situ monitoring of the WF/PC optical bench and housing during a system thermal vacuum test. The diagnostic instrumentation was an invaluable tool in monitoring the internal contamination. The instrumentation allowed the internal environment of the WF/PC to be monitored without altering the functional requirements or nominal operating requirements of the WF/PC.

The TQCM performed in-situ measurements of adsorbed and desorbed VCM on the internal surfaces of the WF/PC. The TQCM measured an organic contaminant, less volatile than water, correlated to the operation of the electronics bays within the WF/PC. The OWS reflectance measurements indicated that if warmed to room temperature and atmospheric pressure, the contaminant did not cause a loss in reflectance on an optical surface.

Although the TQCM temperature was not cold enough to simulate the cooled detectors, verification of ice free operation of the cooled detectors was performed with flat field imaging. The flat field images were not obscured, thus verifying ice free operation of the cooled detectors.

---

[6] Jack B. Barengoltz: Actual WF/PC Venting and Implications for Water Modeling. JPL Interoffice Memorandum No. 354:JB:88:0129, Jet Propulsion Laboratory, Pasadena, CA, May 2, 1988.

REFERENCES

1. Springer, G. S.; et. al.: Environmental Effects on Composite Materials. Westport, CT:Technomic, 1981.

2. Taylor, D.; Barengoltz, J; Jenkins, T.; Leschly, K.; and Triolo, J.: WF/PC Internal Molecular Contamination During System Thermal-Vacuum Test. 15th Space Simulation Conference, NASA CP-____, 1988. (Paper ____ of this compilation.)

3. Extended Range TQCM Engineering Report, Revision C. FAR-78-012, Faraday Laboratories Inc., La Jolla, CA, April 24, 1986.

4. Wide Range Convectron Vacuum Gauges from Granville-Phillips. Product Literature No. 275 177 100, Granville-Phillips Co., Boulder, CO, February 1987.

5. Hansen, P.; Maag, C.; Argoud, M.; Barengoltz, J.; and Taylor, D.: Wide-Field/Planetary Camera Contamination Control Assessment. 15th Space Simulation Conference, NASA CP-____, 1988. (Paper ____ of this compilation.)

6. Westphal, J.: Science Performance Summary. JPL Document No. D-5322 (CM-02), WF/PC I Delta Pre-Ship Review, April 6, 1988.

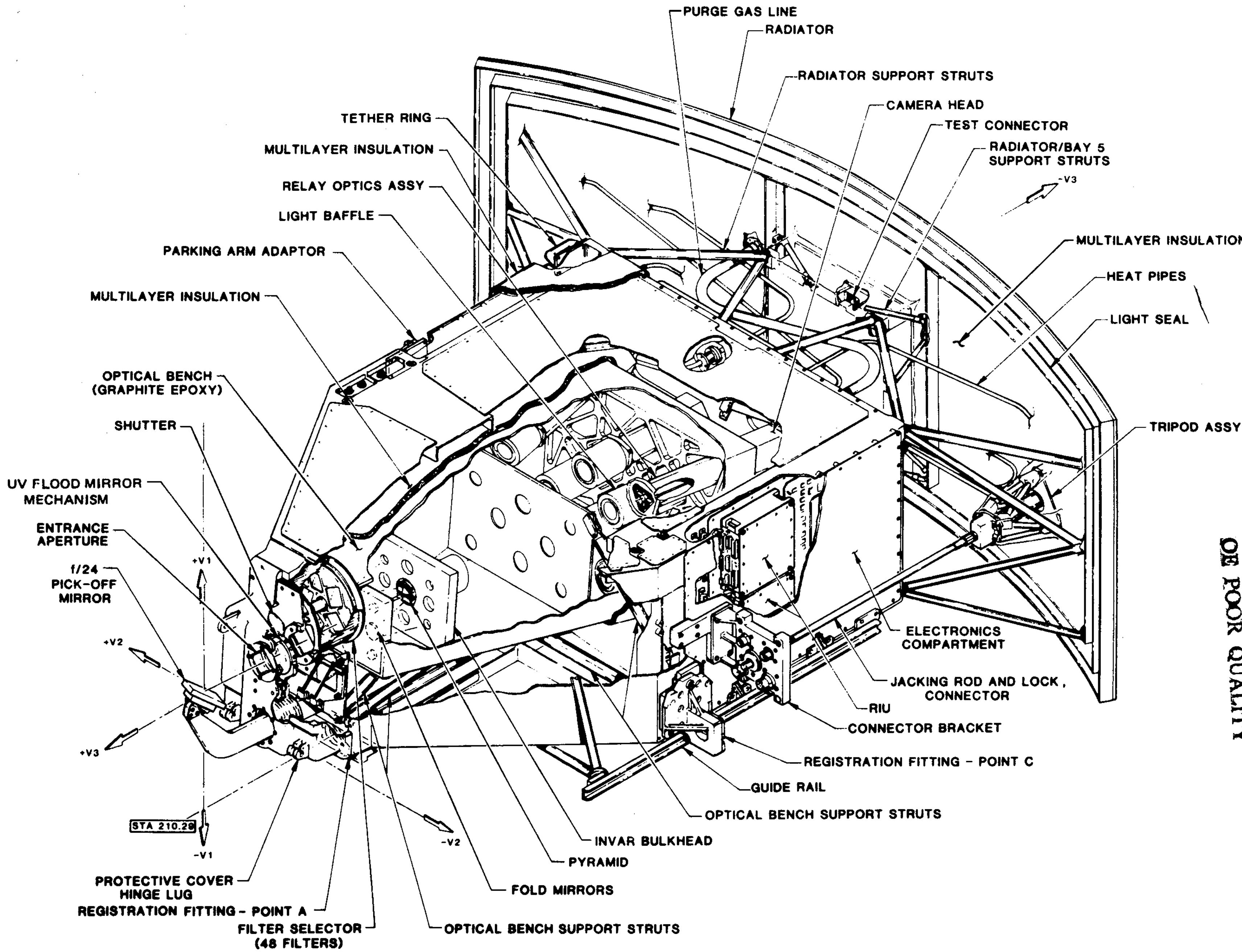

Figure 1. Wide Field/Planetary Camera Cutaway View

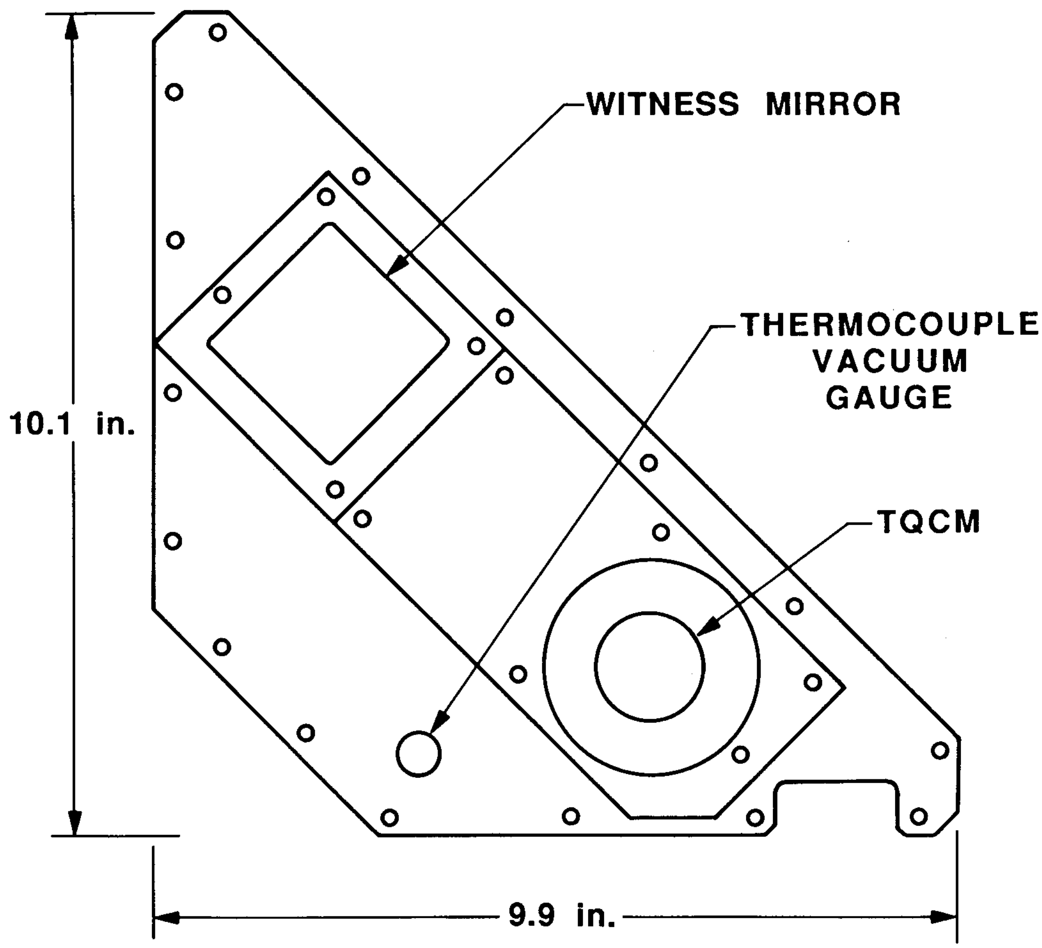

Figure 2. WF/PC Access Plate

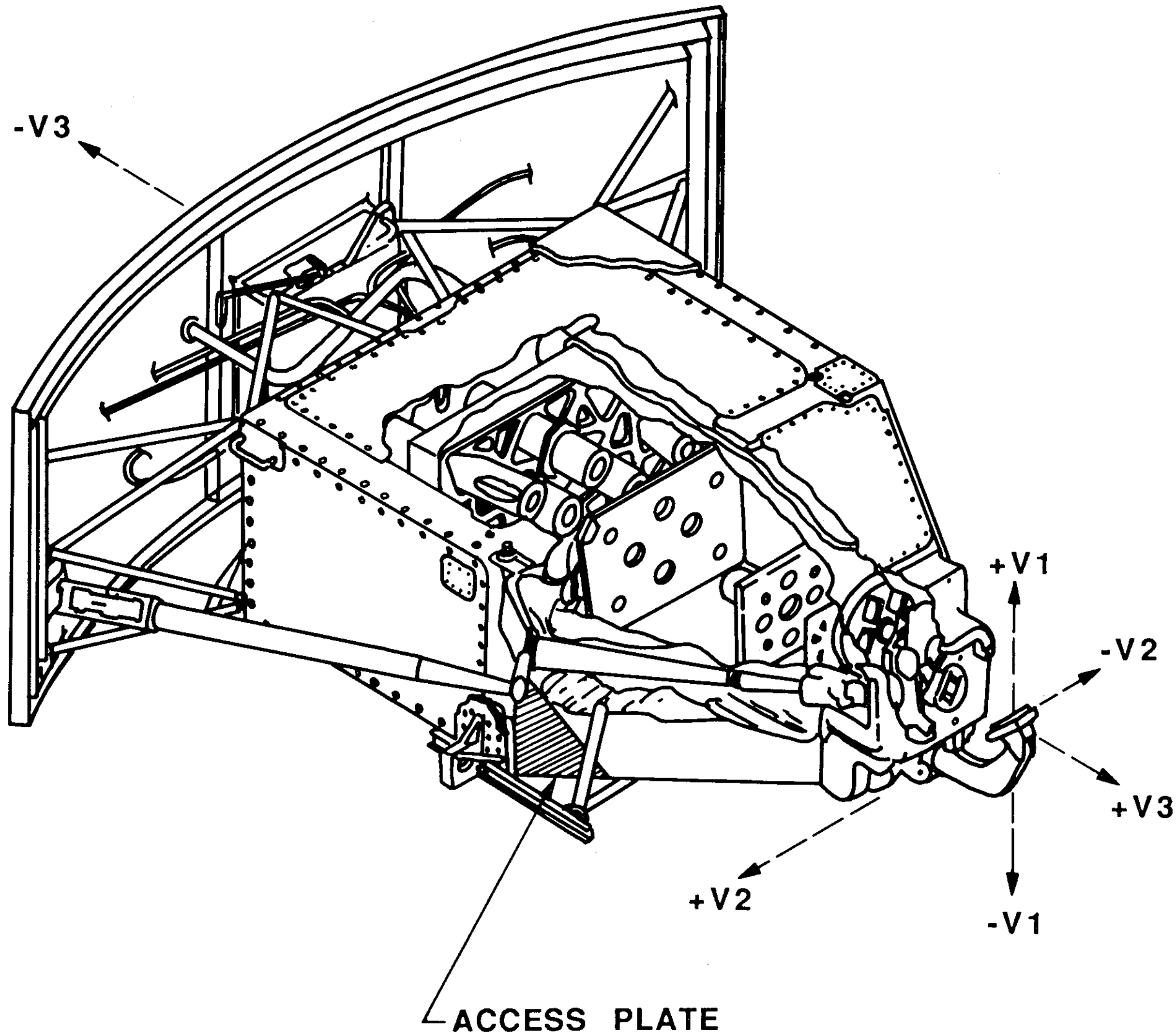

Figure 3. Wide Field/Planetary Camera with Access Plate

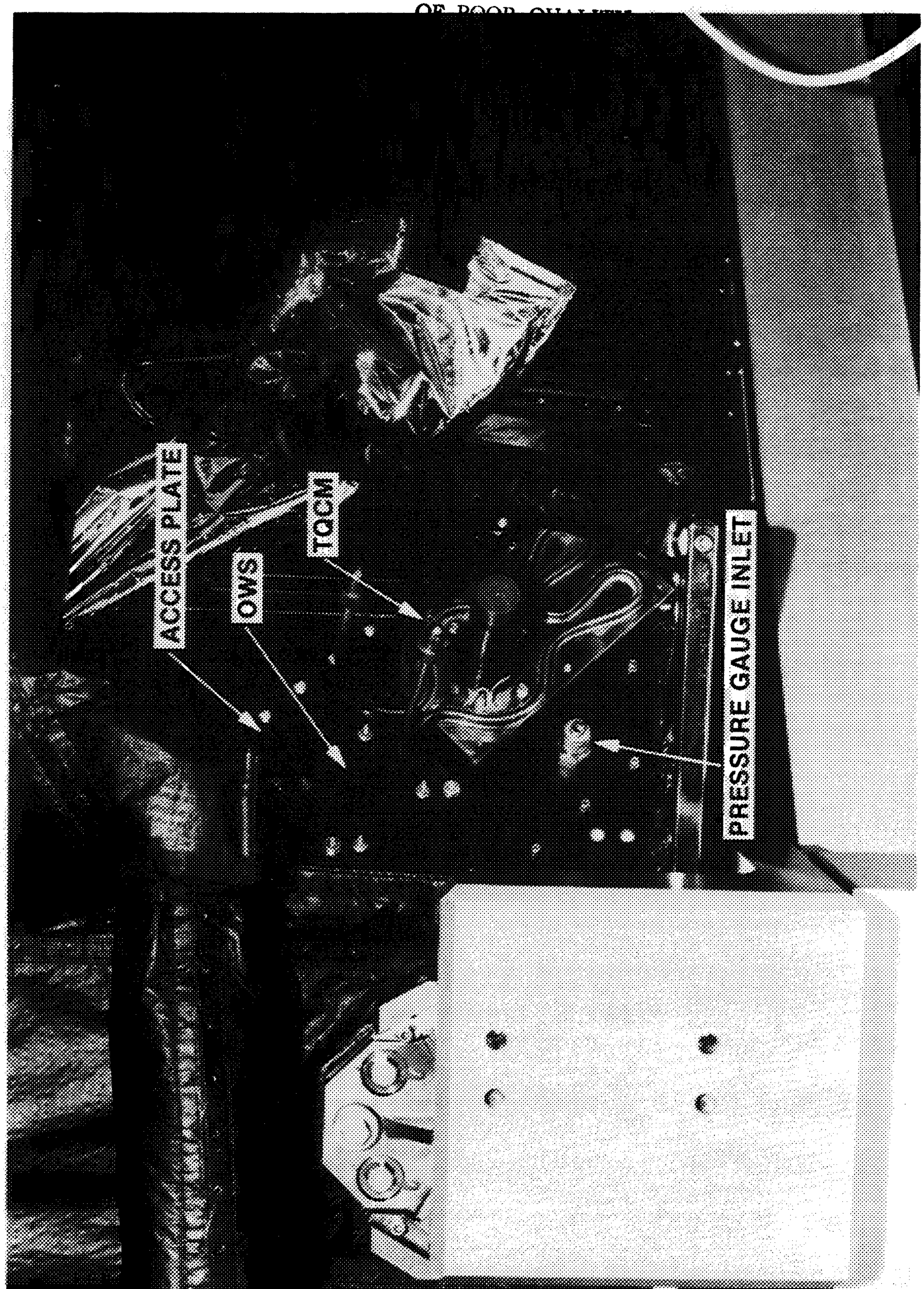

Figure 4. Access Plate Mounted on the Wide Field/Planetary Camera

ORIGINAL PAGE IS
OF POOR QUALITY

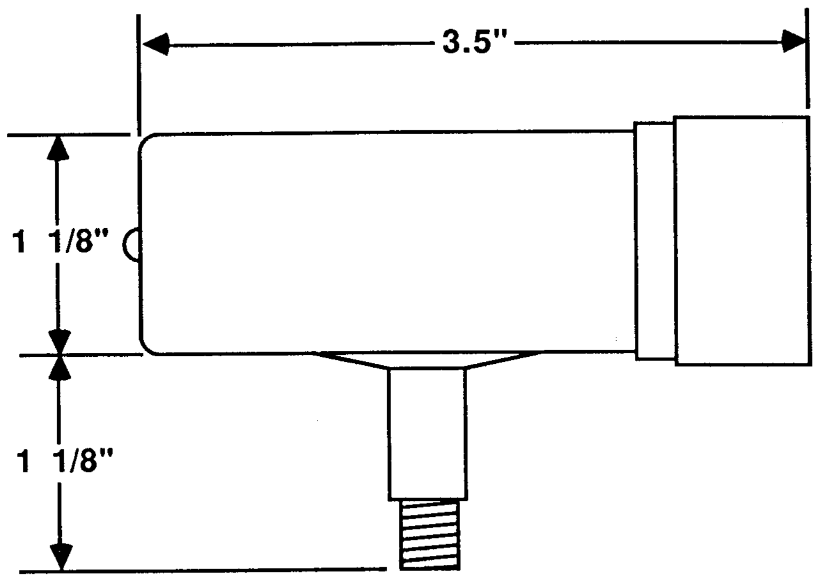

Figure 5. Pressure Gauge

ORIGINAL PAGE IS
OF POOR QUALITY

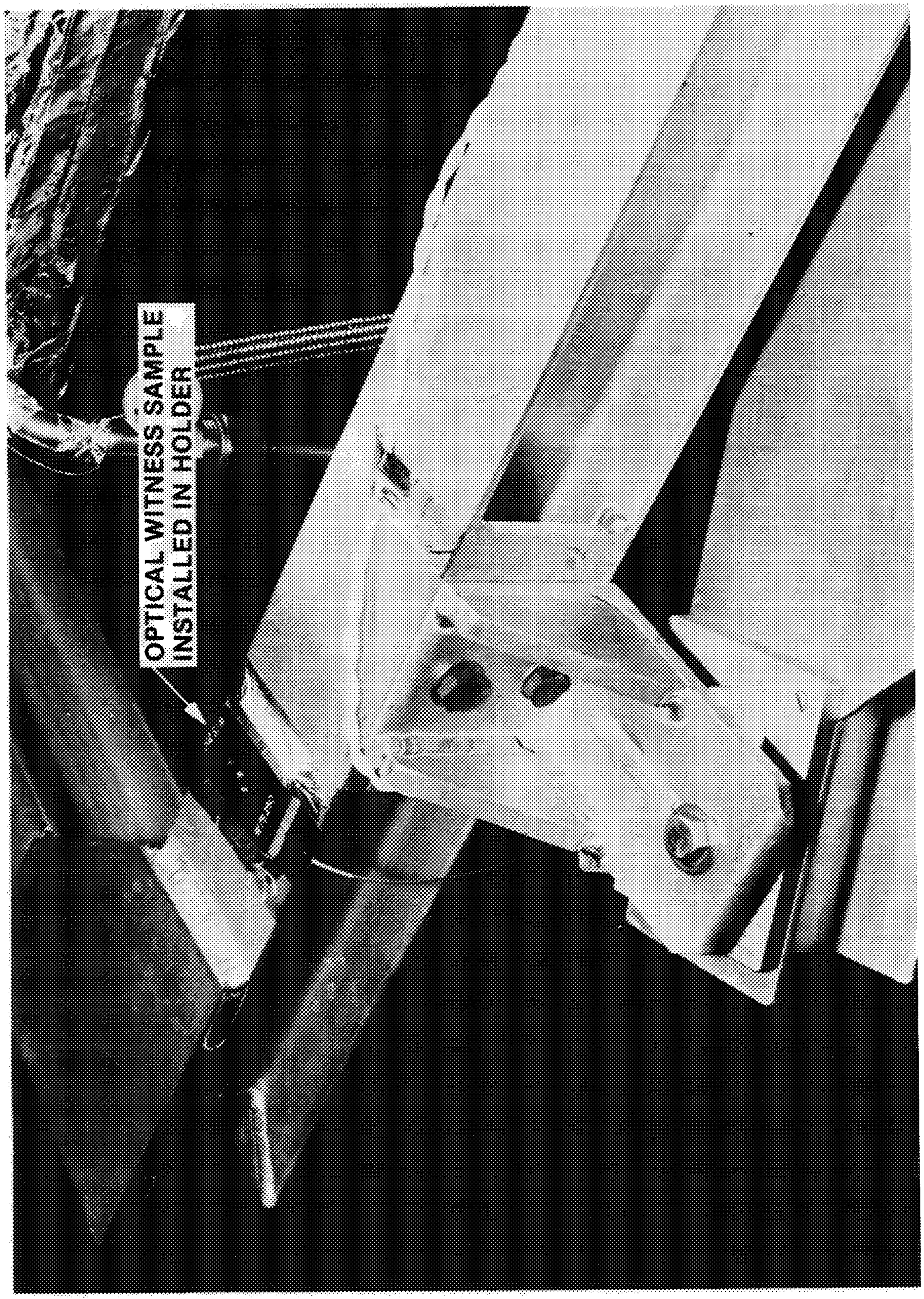

Figure 6. Wide Field/Planetary Camera Optical Witness Sample

Session II

CONTAMINATION II